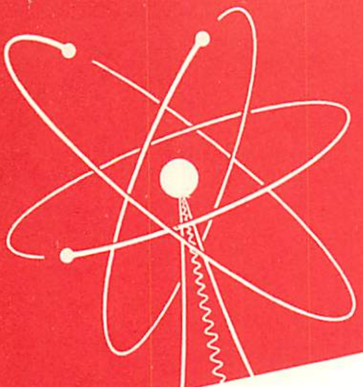
C-6



VIDEO AMPLIFIERS

Lesson T2C-6A

DeVRY Technical Institute
4141 W. Belmont Ave., Chicago 41, Illinois
Formerly DeFOREST'S TRAINING, INC.

T2C-6A

VIDEO AMPLIFIERS

ELECTRONICS TELEVISION
DTI
DeVRY Technical Institute

4141 Belmont Ave.
Chicago 41, Illinois

COPYRIGHT 1956

To provide sharp, clear pictures, peaking coils and low frequency compensation are needed in the video amplifier circuits of television receivers.

Courtesy Capehart-Farnsworth Company

VIDEO AMPLIFIERS

Contents

PAGE

Equivalent Amplifier Circuits 4

  Medium Frequencies 6

  Low Frequencies 7

  Tube Capacitances 7

  High Frequencies 9

Frequency Distortion 10

  Low Frequency Attenuation 11

  Low Frequency Compensation 12

  High Frequency Attenuation 13

  High Frequency Compensation 14

Video Amplifier Circuits 19

  Picture Phase 20

  Contrast Control 21

  Brightness Control 25

Phase Distortion 27

Video Amplifier Troubles 29

Nothing is impossible; there are ways that lead to everything, and if we had sufficient will we should always have sufficient means.

—Rochefoucauld

VIDEO AMPLIFIERS

To produce the image on the screen of a Television receiver, the picture signal is applied to the grid circuit of the picture tube. Developed in the output circuit of the video second detector, this signal has a magnitude of approximately 2.5 volts, peak to peak. To drive the picture tube properly, the signal must be 50 to 100 volts peak to peak. This voltage gain of 20 to 40 times is provided by the **video amplifier.** Also, as explained previously, the picture signal includes information ranging from low rate changes in lighting to the fine picture details. This range of information results in picture signal frequencies which extend down to 20 or 30 cycles and up to around 4 mc.

Because of this wide range of picture signal frequencies, the video amplifier must provide uniform amplification over this entire band.

Since it is impractical to design an inductance which permits acceptable frequency response at both high and low frequency ends of the video band, transformer and impedance coupled circuits are not employed in video amplifiers. Although resistance-capacitance coupling is not ideal, certain corrective measures enable the resistance coupled circuit to provide satisfactory v-f amplification.

EQUIVALENT AMPLIFIER CIRCUITS

In electron tube amplifiers, the various circuit components provide either a path for the signal currents; a means of applying the proper d-c operating voltages to the tube elements; or both. When considering the frequency response, only the signal paths are of concern. Therefore, in some schematic diagrams it is helpful to omit the components which do not directly affect the amplification of the signal voltages. To further help in understanding how the circuit works, the plate resistance r_p of the electron tube may be represented by a resistor symbol. Such a circuit diagram is called an EQUIVALENT CIRCUIT.

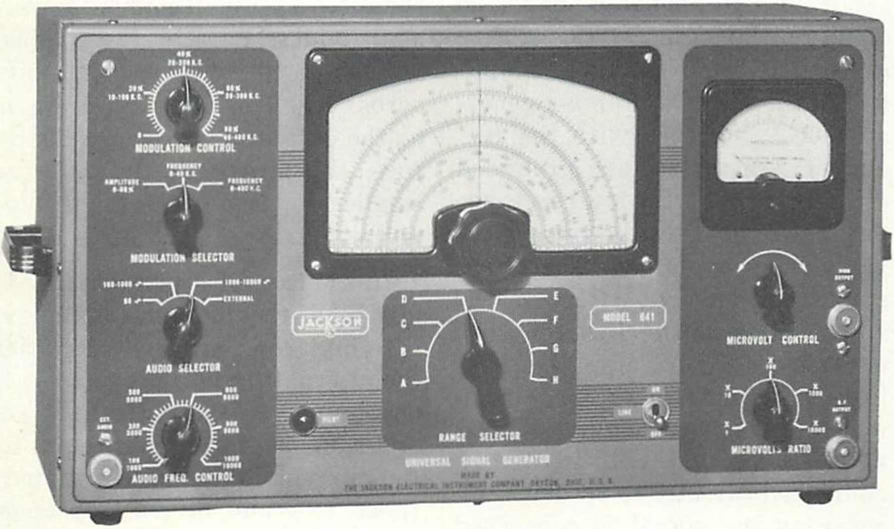
To show that this circuit diagram actually is equivalent to the more conventional schematic, several steps of the conversion process are given in Figure 1. Figure 1A shows a conventional schematic of a resistance coupled amplifier in which tube V_1 is coupled to tube V_2 by plate load resistor R_L, coupling and d-c blocking capacitor C_c, and grid resistor R_g. Also included in this diagram are the cathode circuit components of both tubes, the low voltage power supply, and its bypass capacitor C_f.

In any single amplifier stage, frequency response considerations concern the nature of the variations in output voltage with constant input voltage over the desired frequency band. Thus, as the V_1 output is the signal voltage appearing across the grid resistor of V_2, only this much of the circuit need be shown in an equivalent circuit diagram. This simplification is illustrated in Figure 1B where e_g represents the input voltage, and e_o the output.

In the cathode circuit, resistor R_k is bypassed by capacitor C_k. Therefore, except at the lowest frequencies, C_k serves as the signal path, while R_k is needed merely to maintain the proper d-c voltage on the cathode. Likewise, in the plate circuit, capacitor C_f forms a path for the signal currents which are thus bypassed around the plate d-c supply.

To emphasize the importance of capacitors C_k and C_f insofar as the signal paths are concerned, the diagram of Figure 1B has been rearranged in Figure 1C to give them a more prominent position. Also, the plate resistance of V_1 is represented by resistor r_p. The a-c plate voltage is of greater magnitude than the input voltage e_g. To represent this process the tube is considered as an a-c generator as indicated by the letter "G" inside the tube symbol.

At the very low frequencies, the reactances of capacitors C_k,



When used with an oscilloscope and a detector probe, the sweep generator determines the frequency response characteristics of a video amplifier.

Courtesy The Jackson Electrical Instrument Co.

C_f, and C_c are relatively high and their effects on the output of the amplifier will be explained later in this lesson. However, at all other frequencies, the reactances of these capacitors are so low that they can be neglected, with the cathode of the tube and the B+ end of R_L being considered at ground potential so far as the signal voltages are concerned. In other words, R_k and the B supply are thought of as being "shorted" by the bypass capacitors.

Medium Frequencies

These conditions are indicated in the arrangement of Figure 1D which represents the "equivalent circuit" of the amplifier at medium frequencies. Since the "shorted" components have no effect on the signal voltages, they are omitted and the tube, simplified to the symbol of an a-c generator "G," together with the B+ end of resistor R_L are grounded directly through the low reactance paths provided by the bypass capacitors as explained. Therefore, since they have no effect on the signal, R_k and the B supply are omitted in Figure 1D. Also having negligible reactance at medium frequencies, coupling capacitor C_c is omitted, with R_L and R_g connected directly to r_p. Thus, insofar as the signal is concerned at medium frequencies, R_L and R_g are actually in parallel across the output of the amplifier stage.

In Figure 2A, the circuit of Figure 1D is redrawn with R_{eq} representing the equivalent resistance of R_L and R_g in parallel. The voltage applied by generator G is equal to the a-c grid voltage e_g multiplied by the amplification factor μ of the tube and, therefore, it is shown as μe_g. To clarify the conditions in the output circuit the symbols are rearranged again in Figure 2B to show that the alternating plate current I_p is determined by the amplitude of the applied voltage μe_g and the total resistance of r_p and R_{eq} in series.

In any amplifier, with a given input, the greater the gain or amplification, the greater is the output e_o. As Figure 2B shows, resistances r_p and R_{eq} form a voltage divider. Part of the applied voltage μe_g is across r_p, and part across R_{eq}. The part across R_{eq} is e_o, the output of the stage. Therefore, the larger R_{eq} is, and the smaller r_p, the greater the output, e_o.

In the case of a pentode amplifier tube, the plate resistance r_p is so high compared with R_{eq}, that the alternating plate current I_p is determined almost entirely by μe_g and r_p. Thus, for a given input e_g, the current I_p is directly proportional to μ and inversely proportional to r_p.

The ratio μ/r_p is the transconductance g_m of a tube. Therefore, the higher the g_m the larger the plate current I_p, and the greater the voltage e_o across R_{eq} in Figure 2B. Thus, with a pentode, the amplification obtained is directly proportional to the transconductance of the tube and to the equivalent plate load resistance R_{eq}.

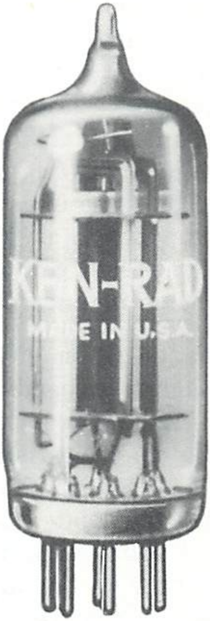
Low Frequencies

As mentioned, capacitors C_k, C_f, and C_c of Figure 1A affect the amplifier response at low frequencies, therefore all of these could be included in a diagram of the equivalent amplifier circuit at low frequencies. However, the effects of C_k and C_f are so slight compared to that of coupling capacitor C_c that usually C_c is the only one included as shown in Figure 3A. Under these conditions, resistors R_L and R_g no longer can be considered in the simple parallel relationship that they have at medium frequencies.

To make a comparison with the circuit of Figure 2B, the equivalent circuit of Figure 3A has been rearranged as shown in Figure 3B. Here, the output voltage e_O is not equal to the I_pR_{eq} given for medium frequencies but is equal to the voltage across R_L minus the voltage across coupling capacitor C_c. Thus, at low frequencies, the increased reactance of the coupling capacitor reduces the output voltage e_O.

Tube Capacitances

As explained previously, a small but definite capacitance exists between the various elements of an electron tube since each element functions as a single plate of a simple capacitor. Other capacitances and capacitance effects also are associated with a tube in a circuit. The total for all of these may be divided into two general classifications: (1) INPUT CAPACITANCE C_I, and (2) OUTPUT CAPACITANCE C_O.



A miniature type sharp cutoff pentode, the 6AU6 is commonly employed in the first stage of a two-stage video amplifier.
Courtesy General Electric Co.

The input capacitance C_I may be divided into four components:

(1) the cold input capacitance C_{cd}, (2) the hot input capacitance C_{ht}, (3) the effect of the grid-to-plate capacitance C_{gp}, and (4) the stray capacitance C_s.

Of these, the first two and the fourth have been explained in detail in a previous lesson. The third factor is a capacitance the magnitude of which depends upon the gain of the stage. That is, with the amplifier stage in operation (in a dynamic state), the input capacitance is considerably greater than the value measured under static or no signal conditions. The increase in capacitance results from what is known as the "Miller effect", and occurs in the following manner.

The charge Q on either plate of a capacitor depends directly upon its capacitance C and the voltage E applied across its plates. That is, $Q = C \times E$. Under static conditions (no plate load), the only signal voltage applied to the grid of a tube is the input voltage, e_g. In this case, the charge on the grid is $q_1 = C_{in} \times e_g$, where C_{in} is the static or cold input capacitance.

In dynamic operation, the difference of potential e_{gp} between the plate and grid places a charge q_2 on the grid. This charge is proportional to e_{gp} and the grid-plate capacitance, C_{gp}. Thus, $q_2 = C_{gp} \times e_{gp}$. With the amplifier in operation, then, the total charge on the grid is $q_1 + q_2$.

$$q_1 + q_2 = C_{in} \times e_g + C_{gp} \times e_{gp}.$$

The voltage on the plate is equal to the input voltage e_g multiplied by the stage gain A. That is, the plate voltage is Ae_g. As the grid and plate voltages in an amplifier are 180° out of phase, the total difference of potential, e_{gp}, is equal to their sum, $Ae_g + e_g$. An equivalent means of expressing this sum is $e_g\ (A + 1)$. Substituting this sum for e_{gp} in the above expression for the total charge on the grid gives:

$$q_1 + q_2 = C_{in} \times e_g + C_{gp} \times e_g(A+1)$$

which can be simplified to:

$$q_1 + q_2 = e_g[C_{in} + C_{gp}(A+1)].$$

Here, the entire portion in brackets represents the input capacitance required to permit the voltage e_g to produce the total charge $q_1 + q_2$ on the grid of the tube.

As mentioned, under static conditions, the input voltage e_g produces only the charge q_1 on the grid. However, under dynamic conditions, the same voltage e_g produces an additional charge q_2. This additional charge effects the grid circuit in the same manner as would the addition of a capacitance equal to $C_{gp}\ (A + 1)$. Therefore, due to the difference between the static and dynamic operation, the Miller effect is thought of as increasing the input capacitance by an amount equal to the grid-plate capacitance multiplied by the stage gain plus one.

Considering all four of the input capacitance components mentioned, the total input capacitance C_1 of an electron tube is:

$$C_I = C_{cd} + C_{ht} + C_{gp}(A+1) + C_s.$$

The OUTPUT CAPACITANCE C_O consists of the tube plate-to-cathode capacitance plus all others in shunt with the output circuit, such as capacitance between the plate and suppressor grid, the plate and screen grid, the plate leads and the chassis.

High Frequencies

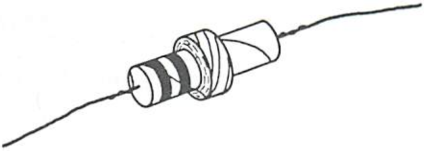
At high frequencies, the tube capacitances have an important effect on the amplifier gain. In Figure 4A, capacitors C_O and C_I represent the V_1 output and V_2 input capacitances, respectively. Considering the B+ at signal ground potential, C_O is in parallel with R_L, and C_I is in parallel with R_g. Following the plan of Figure 1, the components of Figure 4A have been rearranged into Figure 4B and then to Figure 4C where C_T represents the total capacitance of C_O and C_I in parallel and R_{eq} represents the total resistance of R_g and R_L in parallel.

As stated before, the amplification obtained is directly proportional to the μ of the tube when it is a triode, or to the g_m if it is a pentode. Also, the larger the plate load, the greater the output at a given frequency. However, in this case, the plate load includes the reactance of C_T in addition to the equivalent resistance R_{eq}. That is, in Figure 4, the plate load is an impedance Z_L made up of R_{eq} and X_{C_T} in parallel.

As with parallel resistances, the total or equivalent load impedance is equal to the product of R_{eq} and X_{C_T} divided by their sum. However, since the current in C_T is not in phase with that in the resistors, it is necessary to use the vector sum—that is, $\sqrt{R_{eq}^2 + X_{C_T}^2}$. Thus, the equation for obtaining the total load impedance of the circuit of Figure 4 is:

$$Z_L = \frac{R_{eq} \times X_{C_T}}{\sqrt{R_{eq}^2 + X_{C_T}^2}}$$

Since the reactance X_{C_T} varies with frequency, the plate load is not a constant value over the frequency band. As frequency increases, X_{C_T} decreases. The plate load Z_L never can be greater than either R_{eq} or X_{C_T}. Therefore, at the higher frequencies, the decreased capacitive reactance causes Z_L to be smaller than it is at medium frequencies. Since the output e_0 is the voltage across the load Z_L, the decreasing reactance of C_T results in reduced output as frequencies increase. In effect, C_T bypasses high frequency components of the signal.



Small coils wound directly on the resistor which shunts them are used for high frequency compensation in television receivers.

FREQUENCY DISTORTION

In general, r-f, i-f, a-f, and v-f amplifiers are designed to operate with uniform amplification over definite bands of frequencies to provide "flat top" response. Any variation in the gain of an amplifier, within its desired pass band, is called frequency distortion. The frequency range or width of the required pass band varies widely in the different services. For example, standard AM broadcast stations are allocated a 10 kc channel, FM broadcast stations a 200 kc channel, and television boadcast stations a 6 mc channel. The common forms of r-f and i-f amplifiers include tuned circuits designed to provide an approximately even response over the required band pass, the range of which is but a comparatively small percentage of their mean operating frequency.

For example, the common 455 kc i-f amplifier in a superheterodyne broadcast radio receiver has a 10 kc pass band from 450 kc to 460 kc. Thus it requires only a 1.1% increase and decrease from 455 kc to cover the band. In this same type of receiver, the audio amplifier has a pass band of about 50 cycles to 5000 cycles which is approximately half the frequency range of the i-f amplifier. However, the highest frequency is 100 times as great as the lowest frequency. For a high fidelity audio amplifier, with a pass band of 30 to 15,000 cycles per second, the highest frequency is 500 times as great as the lowest frequency.

As explained previously, the video amplifier of a television receiver should have a pass band of 30 cycles to 4,000,000 cycles per second in which the highest frequency is 133,000 times as great as the lowest frequency. To provide a pass band of this width, the resistance-capacitance coupling circuits of the amplifier must be compensated to offset the effect of the various capacitances which reduce the gain at the higher and lower frequencies. This decrease in signal intensity is called "attenuation". Since the causes of low frequency attenuation differ from those of high frequency attenuation, they are explained separately in the following paragraphs.

Low Frequency Attenuation

In the video amplifier circuit of Figure 5A, the input e_I is applied through capacitor C_c to the grid of tube V_1. The output of V_1 is coupled through choke L_2 and capacitor C_b. In a circuit of this type, there are four main causes for reduced amplifier output at the low frequencies. The first cause is that a portion of the applied voltage e_I is across the input coupling capacitor C_c and the remainder across the grid resistor R_g. That is, C_c and R_g make up a voltage divider so that e_I is divided into the two parts, e_{C_c} and e_{R_g} as indicated. Thus, the signal voltage across the grid resistor is somewhat less than the total applied voltage e_I.

At medium and high frequencies, the reactance of C_c is so low that the voltage drop e_{C_c} is negligible. Practically all of the input e_I appears across R_g. However, AT THE LOW FREQUENCIES X_{C_c} is greater and the voltage drop e_{C_c} is a considerable fraction of the input signal e_I.

2 The second cause is due to the fact that the cathode circuit impedance increases as frequency decreases.

So far as the signal voltage e_{R_g} is concerned, the grid-cathode part of the tube is in series with the parallel cathode circuit components, R_kC_k. This results in e_{R_g} being divided into the fractions e_g and e_{R_k} as indicated. That is, the voltage divider action occurs again, and the fraction e_{R_k} is lost as far as amplification is concerned. Therefore e_g is the only part of the input signal voltage actually applied between the grid and cathode of the tube, and it is desirable that the cathode circuit impedance have a low value so that e_{R_k} is small and e_g is a large fraction of e_{R_g}.

3 The third cause is due to the increase in the screen grid circuit impedance with decrease in frequency. Capacitor C_p should maintain the B+ end of resistor R_s at signal ground potential so that R_s and screen bypass C_s are effectively in parallel for signal currents. This is indicated by the dashed line connecting R_s and C_s. Therefore, the screen grid circuit impedance Z_{g_2} can be stated mathematically as follows:

$$Z_{g2}=\frac{R_s\times X_{C_s}}{\sqrt{R_s^2+X_{C_s}^2}}$$

in which X_{C_s} is the reactance of capacitor C_s. Also, as in the cathode circuit, impedance Z_{g_2} becomes higher with decreasing frequencies.

The increase of Z_{g_2} at low frequencies causes fluctuations of the screen voltage, and the resulting variations of current cause the screen potential to swing toward negative when the control grid is swinging toward positive, and vice versa. This action reduces the effect of the control grid on the plate current. Therefore, it is a type of degeneration.

The video amplifier must have good response at low frequencies to reproduce the large areas of sky and shadow with even shading, and good response at high frequencies to reproduce details such as the windows in the buildings.

Courtesy Sentinel Radio Co.

H The fourth cause of low frequency attenuation is the variation of the reactance of the power supply filter components. This reactance increases with decreasing frequency, resulting in degeneration like that explained for the screen grid circuit. However, the power supply affects both the screen and plate voltages.

Low Frequency Compensation

Still referring to Figure 5A, with proper choice of components, the voltage divider action of C_cR_g can be reduced. The capacitance of C_c is made large so that its reactance is small, and the lost voltage e_{C_c} is as low as possible. Also, to cause most of e_I to appear across R_g, a large grid resistance is used.

At low frequencies the main plate load impedance for V_1 is provided by R_L and C_f. As the frequency decreases, the reactance of C_f increases and the stage gain increases by a corresponding amount. This increased gain compensates for the increased voltage drop across the coupling capacitor. Optimum compensation occurs when the time constant of R_LC_f is equal to that of the coupling capacitor and grid load resistor.

The attenuation due to the cathode circuit impedance is minimized in one of the following ways:

1. Eliminating R_k and C_k and grounding the cathode—either grid leak or fixed bias then being used.

2. Eliminating C_k. This results in a loss in stage gain due to the degeneration effect of the unbypassed cathode resistor, but the loss is constant over the frequency band.

3. Making the capacitance of C_k very large and accepting the small low frequency attenuation which still occurs.

The screen grid circuit attenuation of the video amplifier may be corrected by employing a bypass capacitor C_s with a large capacitance.

A fourth measure employed for correction of low frequency response is the compensation network R_fC_f. For signal frequencies, capacitor C_p effectively grounds the B+ end of R_f so that this resistor and C_f are in parallel as indicated by the connecting dashed line.

As in the cathode and screen grid circuits, the parallel combination R_fC_f has an impedance Z_f which rises with decreasing frequencies. However, Z_f is in series in the plate circuit and therefore results in an increase in total plate load impedance with decreasing frequencies. Being proportional to the plate load impedance, the gain of the amplifier is higher at low frequencies than at medium frequencies. Thus, R_f and C_f compensate for the low frequency attenuation in the cathode circuit of the video amplifier tube. Optimum correction occurs when the time constants of R_kC_k and R_fC_f are equal.

High Frequency Attenuation

In Figure 5A, C_0 represents the output capacitance of V_1, and C_I the input capacitance of the following stage. As explained, the reactance X_{C_T} of C_0 and C_I in parallel is a component of the total load impedance Z_L in the plate circuit of the tube. The total impedance of a parallel circuit is determined mainly by the impedance of its smallest branch. Therefore, at the medium and low frequencies, Z_L is approximately equal to R_{eq}, because X_{C_T} is very high at these frequencies. As frequency increases, the reactance of C_T becomes lower. Finally, at some high frequency, X_{C_T} decreases to R_{eq}. For convenience, we may call this frequency f_o. Thus, at frequencies above f_o, X_{C_T} is less than R_{eq}, and the total impedance Z_L is approximately equal to X_{C_T}.

However, since the capacitive reactance X_{C_T} decreases with rising frequency, the load impedance Z_L becomes lower also as frequencies increase above f_o. As explained, the stage gain is directly proportional to the plate load impedance. Therefore, as frequencies rise, the stage gain drops off at the high frequencies. Output capacitance C_o and input capacitance C_I cause the greatest high frequency attenuation.

High Frequency Compensation

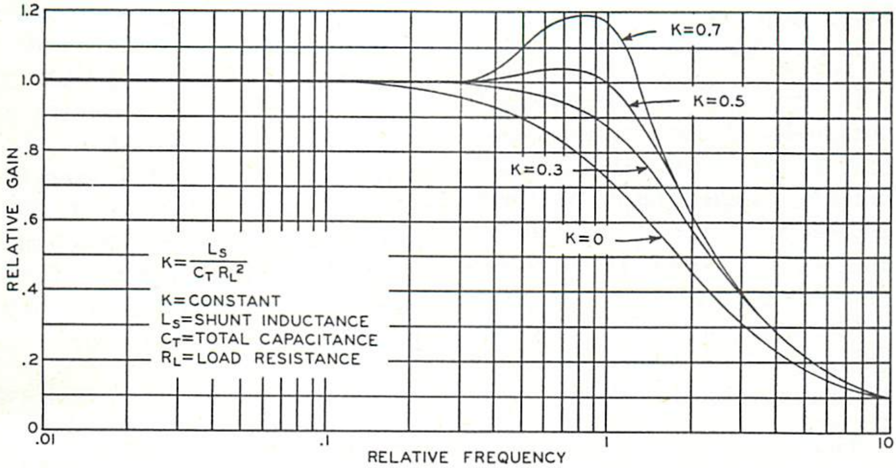
To obtain a flat or even response over the band that is to be amplified by the video circuits, the stage gain should remain constant. For constant stage gain then, the load impedance Z_L should not vary with frequency. To achieve this condition, the frequency f_o should be the upper limit of the desired pass band. That is, f_o should equal approximately 4 mc. At all frequencies below f_o, R_{eq} is less than X_{C_T}. Therefore, the load impedance Z_L is approximately equal to R_{eq} over the desired band. As resistance does not vary with frequency, Z_L and the stage gain remain constant over the band.

With a given amplifier tube, circuit, and stage gain, the total capacitance C_T is fixed. Thus, to attain the desirable condition mentioned, circuit resistances can be selected such that their equivalent resistance R_{eq} is equal to the reactance of C_T at the upper limit of the band. As shown in Figure 4, R_{eq} consists of R_L and R_g in parallel. Ordinarily, R_L is much smaller than R_g, therefore R_L mainly determines the value of R_{eq}.

As an example, in Figure 4A, suppose the circuit of V_1 has an output capacitance C_o of 11 $\mu\mu$f, and the input capacitance C_I of the next stage is 9 $\mu\mu$f. Then, the total capacitance C_T is $11 + 9 = 20$ $\mu\mu$f. At 4 mc, 20 $\mu\mu$f capacitance offers a reactance of approximately 1600 ohms. On this basis, the load resistor R_L would have a value of 1600 ohms, thus making R_{eq} approximately equal to X_{C_T}.

In actual commercial video amplifier circuits, other compensation methods are used which permit a larger plate load resistance than the above example value. Typical plate load resistances range from 4000 to 8000 ohms. However, even these values are very low compared with the plate loads employed in audio amplifiers. Thus, in video amplifiers, one method of obtaining the required wide band response consists of using a low value plate load resistor to minimize the effect of the circuit shunt capacitances.

As mentioned, the stage gain is proportional to the transconductance of the tube as well as to the load impedance. With the relatively low value plate load resistors used in video amplifier circuits, it is necessary to employ tubes with high transconductance in order to obtain the required gain. For example, the type 6BD6, used as an r-f or i-f amplifier in some radio receivers, has a transconductance of 2550 micromhos.



The gain curves of a shunt compensated amplifier for three different inductances.

In contrast, typical tubes employed as video amplifiers in television receivers are the 6AN8, 6CL6, and 12BY7, with transconductances of 6200, 11,000, and 12,000 micromhos, respectively.

Because they have relatively small grid-plate capacitance, pentode tubes have an advantage over triodes as video amplifiers. As explained, the grid-plate capacitance increases the input capacitance by the factor C_{gp} (A + 1). As a comparison, suppose a stage gain of 30 is required. The triode type 12AU7 has a grid-plate capacitance of 1.5 μμf. The Miller effect produces an input capacitance of:

$$C_{gp}(A+1) = 1.5(30+1) = 1.5 \times 31$$
$$= 46.5\ \mu\mu\text{f}.$$

The pentode type 12BY7 has a grid-plate capacitance of .063 μμf. In this case, the input capacitance due to the Miller effect is only:

$$C_{gp}(A+1) = .063(30+1) = .063 \times 31$$
$$= 1.95\ \mu\mu\text{f}.$$

Thus, although the 12BY7 pentode has a static input capacitance of 10.7 μμf, its input capacitance increases to only 12.65 μμf under dynamic conditions. On the other hand, the 12AU7 triode has a static input capacitance of only 1.8 μμf, but its input capacitance increases to 48.3 μμf in operation.

Besides low resistance plate load resistors and high transconductance tubes, special methods of interstage coupling are used to compensate for the attenuation of high frequencies. One method is to connect coil L_1, Figure 5A, in series with R_L, as shown. The reactance of L_1 rises with frequency, causing an increase in total load impedance Z_L and, therefore, stage gain.

In circuits in which coil L_2 is not employed, capacitance C_I adds to C_o to give a total shunt capacitance C_T. Neglecting R_L, C_T forms a parallel circuit with L_1 the inductance of which is so chosen that this parallel circuit is resonant at a frequency f_r, somewhat above the band over which uniform response is desired.

Thus, as shown by the curve of Figure 5B, the amplifier response reaches a maximum at f_r and is flat over the desired range of high frequencies. Because of the rise in the response at f_r, coil L_1 is called a **peaking coil,** and since L_1 is in shunt with C_o and C_I, this method of high frequency compensation is called SHUNT PEAKING.

Known as SERIES PEAKING, another system employs the coil L_2 connected as shown in Figure 5A. In circuits where L_1 is not employed, the lower end of R_L is maintained at signal ground potential by capacitor C_f. L_2 isolates C_I and C_o, and therefore, only C_o is directly in parallel with R_L.

Here the resistance of R_L may be chosen with reference to the reactance of C_o and, as this reactance is higher than that of $C_o + C_I$, R_L may have more resistance, resulting in a higher stage gain. At the high frequencies, the reactance of coupling capacitor C_b is negligible, and the inductance of L_2 is chosen so that this coil and capacitance C_I form a series resonant circuit from the plate of V_1 to ground. L_2 and C_I are made resonant to some frequency f_r above the video band and thus the voltage across C_I is maximum at f_r, as indicated by the output-vs-frequency curve of Figure 5B.

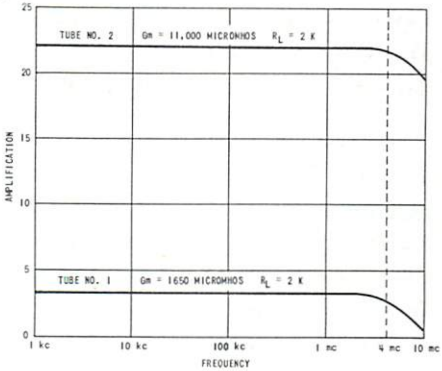
Still greater amplification may be obtained by using both coils L_1 and L_2, in which case the system is termed SERIES-SHUNT PEAKING. As before, coil L_2 forms a series resonant circuit with C_I, while L_1 forms a parallel resonant circuit with C_0, both circuits being tuned to a frequency somewhat above the video band. This arrangement permits the resistance of R_L to be as much as 1.8 times that used in simple shunt peaking, with the stage gain being increased in like proportion. A disadvantage is that this system is critical with respect to the component values and the ratio of C_0 to C_I. Unless this ratio and the various components are exact, the high gain is not obtained.

As an example of the use of frequency compensating components in commercial equipment, Figure 6 shows the video frequency amplifier circuits of a typical television receiver. Operating as a diode detector, the V_1 section of a double triode tube functions as the video detector having the load resistor R_1 and shunt peaking coil L_1. The output of the detector is taken from the plate end of L_1 and coupled directly through series peaking coil L_2 to the grid of the first v-f amplifier V_2.

Although it is not indicated in the diagram, the output capacitance of tube V_1, in parallel with the load L_1R_1, forms the i-f filter. To eliminate low frequency attenuation in its circuit the cathode of V_2 is grounded directly. Due to the direction of current in V_1, the tube end of R_1 is negative with respect to ground and the grid bias for V_2 is obtained from this point through L_2.

The plate circuit of V_2 contains shunt peaking coil L_3, load resistor R_2, and a low frequency compensation R_2C_1. The output from this stage is coupled through series peaking coil L_4 and capacitor C_2 to the grid of the second v-f amplifier stage, V_3. The plate circuit of V_3 includes shunt peaking coil L_5 in series with load resistor R_5, and direct coupling through series peaking coil L_6 to the grid of picture tube V_4.

From the cathode of V_4, the signal circuit is completed through capacitor C_3 to ground. With direct coupling from the plate of V_3, the grid of V_4 is at a positive potential with respect to ground. Therefore, to secure the proper operating conditions for the picture tube, the cathode is made more positive than the grid by supplying the cathode with a higher d-c potential from the slider on potentiometer P_1.



Increase in amplification obtained by use of high transconductance tube, No. 2, designed for video amplifier application, over that provided by ordinary pentode, tube No. 1.

Up to this point, methods of high frequency compensation have been described in terms of what is known as "circuit network theory." However, design engineers also may approach the problem from the standpoint of "electric wave filter theory," in which case the video amplifier coupling circuit is considered a low pass filter. Although it may seem strange to deal with the problem of high frequency compensation by utilizing a low pass filter, it must be remembered that the video coupling circuit must provide uniform response to all frequencies below the "cutoff" at approximately 4 mc, and attenuate all higher frequencies.

Although the details of wave filter theory are not taken up here, Figure 7A shows the basic circuit of the type of filter designed from this theory for video amplifier coupling circuits. Known as a PI-TYPE, LOW-PASS FILTER, this arrangement may be designated also as a MID-SHUNT, CONSTANT K LOW-PASS FILTER. Briefly, the action is that, as frequency rises, the reactance of coil L_1 increases and the reactances of capacitors C_1 and C_2 decrease in such a way that the total impedance of the filter remains constant up to a point called the "cutoff frequency." All signals higher than the cutoff frequency are greatly attenuated.

Mathematical equations have been derived which permit engineers to calculate the respective values of L_1, C_1, and C_2 for any desired cutoff frequency.

When a sharper cutoff characteristic is desired, the circuit of Figure 7A may be extended to include two or more sections connected in series or cascade. Known as a TWO SECTION CONSTANT K FILTER, Figure 7B, is employed commonly in video amplifier coupling circuits. In practical receiver circuits, the tube input, tube output, and stray circuit capacitances replace the capacitors indicated as C_1, C_2, and C_3.

A simplified drawing of this arrangement is given in Figure 7C, where C_1 indicates the output capacitance of the video amplifier tube, C_2 the input capacitance of the cathode ray tube, and C_3 the stray circuit capacitance. To obtain constant output, it is necessary that the impedance of the filter remain constant over the desired frequency band. However, it is characteristic of this type of filter to have a rising impedance as the signal frequencies approach the cutoff value.

To reduce this rise of impedance near the cutoff frequency, resistor R_1 is placed in the load circuit to lower the Q of L_1. This "swamps" the coil to a low, broad resonant response.

Figure 7C has been arranged to show how the various filter components correspond to their respective counterparts in the basic circuit of Figure 7B. However, in actual schematic diagrams of video amplifier coupling circuits, the arrangement of Figure 7C will seldom be found, as these diagrams are drawn on the plan of Figure 7D.

Here, the filter capacitances are not indicated, and with the other components rearranged, there appears to be little likeness between this coupling circuit and the filter of Figure 7B. However, close inspection of both shows them to be electrically equivalent.

In Figure 7D, L_1 and L_2 are in series, with their junction coupled by capacitor C_4 to the grid of tube V_2. The output capacitance of V_1 forms the first capacitor of the filter, the input capacitance of V_2 forms the second capacitor, while stray capacitance between the supply end of L_2 and chassis forms the third capacitor. R_1 is connected in parallel with L_1 as in Figure 7C, and for signal frequencies, the B+ end of R_L is grounded through C_5, therefore the electric location of R_L is the same in both circuits.

VIDEO AMPLIFIER CIRCUITS

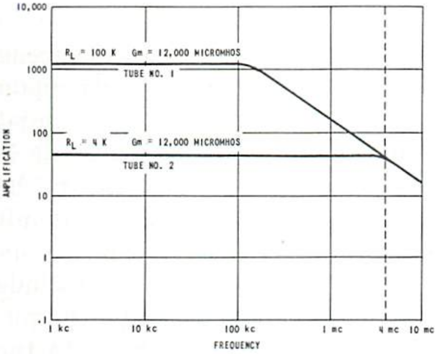
Two-section, constant K filters are employed in the v-f amplifier section of the typical receiver of Figure 8. This receiver has two stages of v-f amplification between the diode detector V_1 and the picture tube V_4. Between V_1 and the first v-f amplifier tube V_2, the filter consists of coils L_2 and L_3, the output capacitance of V_1 plus that of capacitor C_1, the input capacitance of V_2 and the stray capacitances between the supply end of L_3 and the chassis. Resistors R_1 and R_2 correspond respectively to R_1 and R_L of Figure 7D. In Figure 8, R_2 serves also as the load resistor for the detector.

A second filter, used as the coupling circuit between V_2 and the video output amplifier, V_3, consists of L_4, L_5, and the various tube and stray circuit capacitances. As explained before, resistor R_3 prevents the impedance of the first section from rising too far near cut off. In like manner, R_4 swamps the second filter section and also serves as the plate load resistor for V_2. Resistor R_4 and capacitor C_4 function as a low frequency compensating network.

The frequency response of the V_3 stage is somewhat adjustable by means of the terminal strip and jumper arrangement which permits capacitor C_5 to be connected into or omitted from the circuit, as desired. With the jumper across terminals 1 and 2 of the terminal strip, C_5 is connected in parallel with cathode resistor R_8. With the jumper across terminals 2 and 3, C_5 is disconnected from the circuit.

Between V_3 and the picture tube, a third two-section constant K filter consists of tube and circuit capacitances, coils L_6 and L_7 and loading resistors R_9 and R_{10}. In this receiver, the cathode of the picture tube is connected directly to ground, and the grid is made negative with respect to the cathode by its connection through R_{11}, R_{12}, R_{13}, and R_{14} to the slider on potentiometer P_1.

Another common video amplifier circuit arrangement is shown in Figure 9. Here, a single v-f stage amplifies the detector output to the level required to drive the picture tube. The crystal diode detector D_1 rectifies the i-f signal to produce the video signal across load resistor R_1. A three-section low pass filter is formed by coils L_1, L_2, and L_3, the stray capacitance of the crystal to ground, capacitor C_1, and the input capacitance of tube V_1. From the junction between L_2 and L_3, the detector output is applied to the 4.5 mc sound i-f amplifier, the details of which will be explained in a later lesson.



With the same transconductance, amplifier tube No. 1 has flat response up to about 100 kc, while amplifier tube No. 2 has a response which is flat up to about 4 mc. The difference is due to the considerably smaller plate load resistor used with tube No. 2.

Also, from the junction between L_2 and L_3, the video signal is applied through R_2 to the grid of the video amplifier. Cathode bias is obtained by means of resistors R_3 and R_4 which are unbypassed to provide some low frequency compensation. In addition, any "noise" pulses in the signal which have greater amplitude than the cathode bias drive the grid slightly positive. Grid current results, producing a voltage across R_2 such that the grid end of this resistor is negative. This voltage adds to the bias, thus limiting the positive swing of the grid. Thus, R_2 serves to prevent noise voltages from appreciably affecting the plate current of the video amplifier.

Picture Phase

In the symbol for the germanium crystal detector diode D_1, the vertical bar represents the cathode, and the triangle the anode. The electron flow is from the cathode to the anode, through L_1, L_2, L_3, and R_1 to ground, and from ground through the secondary of T_1 to the cathode of D_1. This varying direct current produces a voltage across R_1 such that the ungrounded end of this resistor is negative.

The largest amplitude portions of the video signal represent the blanking and sync pulses, and make the upper end of R_1 more negative than the picture variations. This condition is illustrated by the wave-form drawn above the V_1 input circuit. Although all the parts of this signal are negative with respect to ground, the picture portions are positive with respect to the blanking and sync pulses. Therefore, it is called a "positive picture phase" signal. The action of the video amplifier is to increase the amplitude of the video signal such that there is a greater difference between the most positive and most negative peaks.

Also, as shown by the waveform near the picture tube input circuit, the picture signal variations, sync and blanking pulses have greater amplitude also. Here, the signal has "negative picture phase" as a result of its inversion by the amplifier. The peaks of the picture signal which rise in the direction of the blanking pulse produce the darker parts of the picture. The peaks of opposite polarity produce the lighter parts of the picture. The greater the amplitude of the signal, the greater the potential difference between the positive and negative peaks of the signal. That is, the higher the amplitude of the video amplifier output, the greater the difference in illumination between the light and dark areas of the reproduced picture.

Contrast Control

In television, the degree of difference between the lightest and darkest areas of the image produced on the cathode ray tube screen is called **contrast.** When the light portions of the picture are very light while, at the same time, the dark portions are very dark, almost black, the picture has high contrast. On the other hand, if the picture consists entirely of grey tones only slightly different in shading from one another, the picture contrast is low.

Normally, it is desirable that the contrast be such that the picture on the receiver screen corresponds as closely as possible to the range of shading in the scene at the studio. Depending upon the strength of the video signal applied to the picture tube, it is possible for the contrast to be too great or too little. To permit adjustment to the desired contrast, television receivers include a means of changing the amplitude of the signal applied to the grid or cathode of the picture tube. In the circuit of Figure 9, this adjustment is accomplished by varying the amplification or gain of the video amplifier. As indicated, the cathode resistors R_3 and R_4 are unbypassed. With no cathode bypass capacitor, the plate current changes produce a varying direct voltage across the cathode resistors.

As the grid swings positive, the increased plate current increases the voltage across R_3 and R_4 to cause the cathode to swing positive also. When the grid swings negative, the reduced plate current decreases the voltage across the cathode resistors, and the cathode swings negative along with the grid. The variation of cathode voltage in phase with the signal on the grid reduces the grid control of plate current. Called degeneration, this action decreases the amplification of the stage.

This television receiver console has controls at the side and a shelf which provides a convenient display area.

Courtesy Bendix Radio Division of Bendix Aviation Corp.

The varying voltage across the cathode resistors is called degenerative feedback. Adjustment of the variable resistor R_4 permits changing the degenerative feedback voltage, and therefore, the amplification of the stage. Thus, R_4 is the **contrast control.** When the slider on R_4 is moved to add more resistance in the cathode circuit, the degenerative feedback is increased, the amplification decreased, and the picture contrast decreased. When the slider is adjusted to reduce the cathode circuit resistance, the smaller feedback permits greater amplification and the picture has more contrast.

Since degenerative feedback reduces the stage gain, it effectively decreases the input capacitance added due to the Miller effect. This circuit arrangement permits better response at high frequencies.

In the plate circuit of V_1, a constant K low pass filter is formed by coils L_4 and L_5 and the associated circuit capacitances. Usually, these coils are referred to as series and shunt peaking coils respectively, regardless of the basis of the coupling circuit design. The plate load resistor consists of two parts, R_6 and R_7 which form a voltage divider so that a somewhat smaller video signal voltage is applied to the agc circuit than to the sync separator. The purpose and operation of agc circuits and sync separators are explained in other lessons of this series.

In the circuit of Figure 9, coil L_5 isolates the input capacitance of the picture tube from that of the sync separator tube. Between R_7 and (225 V) B+, a second shunt peaking coil L_6 further improves the high frequency response. R_8 is connected across L_6 to prevent excessive peaking at the resonant frequency of L_6 and its associated capacitances.

The screen grid of the video amplifier tube is placed at ground potential so far as the signal is concerned by the two capacitors C_2 and C_3. To reduce the screen circuit impedance to a very low value at the low frequencies, capacitor C_2 is an electrolytic with a value of 5 μf. The inductance associated with a capacitor of this size is great enough to present appreciable inductive reactance at the high frequencies. Therefore, the .004 μf capacitor C_3 is included to provide a low reactance path to ground for the high frequency alternating components of the screen current.

From the junction between peaking coils L_4 and L_5, the video signal is coupled through R_9 to the cathode of the picture tube. On the screen of the picture tube, the lighter areas of the image are produced when the picture signal makes the grid swing in the positive direction to increase the intensity of the scanning beam. To obtain this desired action, the signal must be applied between the grid and cathode with the proper polarity. That is, the parts of the signal corresponding to the light areas of the scene must be in a direction to make the grid less negative with respect to the cathode. Likewise, the blanking pulses and the parts of the signal corresponding to the dark areas in the scene must make the grid more negative with respect to the cathode.

If the signal is applied to the grid of the picture tube, it must have positive picture phase to provide this action. However, when it is applied to the cathode of the picture tube, the signal must have negative picture phase as shown in Figure 9. Here, the blanking pulse and "dark" portions of the signal drive the cathode positive, while the grid is maintained at a constant potential as determined by the setting of R_{13}. Making the cathode swing positive is equivalent to making the grid swing negative. In either case, the beam intensity reduces and the light on the screen is decreased. On the other hand, the "light" portions of the signal make the cathode less positive, the beam intensity increases, and the screen image becomes brighter.

Each video amplifier stage of the common grounded cathode type inverts the video signal.

Thus, when the receiver employs one video stage, as in Figure 9, the phase of the detector output must be opposite that required at the input to the picture tube. In a receiver having two video stages, the detector output and picture tube input signals have the same phase. For example, in Figure 8, the V_1 current makes the ungrounded end of load resistor R_2 negative to produce a positive picture phase video signal. This signal is inverted by V_2 and again by V_3 to be applied as a positive picture phase signal to the grid of the picture tube.

If, for any reason, the signal applied to the picture tube has polarity opposite that which it should have, a negative picture is produced. That is, the parts which should be light are dark and those that should be dark are light. This undesirable condition can be produced when a replacement crystal detector is connected in the wrong direction. If the connections to D_1 were reversed in Figure 9, the diode current would make the ungrounded end of R_1 positive to produce a negative picture phase signal. Inverted by V_1, this signal would be applied with positive picture phase to the V_2 cathode and result in a negative picture. Therefore, when crystal diodes are replaced, care should be taken to observe the proper cathode and anode connections.

In a receiver with more than one video stage, one stage may become inoperative, and therefore reduce by one the number of signal inversions. However, the signal may still pass through the stage by capacitive coupling through the interelectrode capacitances of the tube. When this action occurs, a weak signal of wrong picture phase is applied to the picture tube. The picture produced lacks contrast and is negative. As explained in an earlier lesson, overloading in the video i-f amplifier is a third cause of negative picture.

In addition to its various alternating components, the video signal contains a direct component. This **d-c component** provides information regarding the average brightness of the background of the televised scene. As will be explained in detail later, the radiated r-f signal carries this background information by varying the amplitude of the background brightness with respect to the blanking pulse components. This information can be used in the receiver to produce a faithful image of the studio scene.

In every receiver, the d-c component is present in the output of the second detector. Many receivers are designed to convey the background information from this point to the picture tube. One method is illustrated by the circuit of Figure 9. In this circuit, there are no d-c blocking capacitors between the detector load and the grid of V_1, or between the plate of V_1 and the cathode of V_2.

A sharp-cutoff pentode commonly employed as the video output amplifier, the 12BY7 has a transconductance of 12,000 micromhos and grid-plate capacitance of 0.063 micromicrofarads.

Thus, from across R_1, the d-c component of the signal is applied directly through R_2 to the grid of V_1 to establish the operating point of the video amplifier. Determined by this operating point, the direct component of plate current produces a d-c component of plate voltage which is coupled directly through R_9 to the cathode of the picture tube. In this way, the operating point of the picture tube corresponds to the magnitude of the d-c component of the detector output.

Because d-c blocking capacitors are not employed, the video amplifier of Figure 9 is termed a direct-coupled amplifier. In this circuit, the voltages across R_1, R_3 and R_4 all add to provide the total bias between grid and cathode of V_1. In the picture tube input circuit, the plate voltage of V_1 is applied across the voltage divider consisting of R_9 and R_{10}. The portion of this voltage across R_{10}, shown as 150 volts, is applied to the cathode of V_2 to provide a no-signal operating condition. R_{11} and R_{13} form a second voltage divider between B+ and ground. From the slider on R_{13}, 115 volts are applied through R_{12} to the grid of V_2. Thus, the picture tube grid is 35 volts negative with respect to the cathode.

Brightness Control

This bias can be changed as desired by adjusting R_{13}. The picture tube bias determines the **brightness** level which the entire screen has with no picture signal applied. When a signal is applied, the d-c component adds to the bias to establish the brightness level of the picture background. This background brightness can be increased or decreased by adjusting R_{13}. Thus, the bias adjustment R_{13} is called the **brightness control.**

Unlike the contrast control, the brightness control does not affect the amplitude of the video signal. It is important to understand the difference between these two controls. As explained earlier, when the contrast control is advanced, the result on the screen is a greater difference or range between the brightest and the darkest elements in the picture. The bright areas become brighter and the dark areas darker. On the other hand, the brightness control changes all of the areas in the same direction. That is, when the brightness control is advanced, both light and dark areas become lighter. When this control is turned the other way, all parts of the picture become darker.

In addition to retaining the d-c component of the signal, the direct-coupling arrangement provides good response at low frequencies. This condition is due to the fact that the low frequency attenuation caused by coupling capacitors is eliminated.

Another circuit arrangement commonly employed to couple the video amplifier to the picture tube is that shown in Figure 10. Here, the plate circuit contains the primary of transformer T_1. This primary and capacitor C_1 form a parallel tuned circuit known as the **sound trap** which is tuned to resonance at the sound i-f of 4.5 mc. The secondary of T_1 and capacitor C_2 couple the 4.5 mc i-f through C_3 to the input of the sound i-f amplifier.

The sound trap has little reactance at video signal frequencies. Therefore, the video signal voltage appears across the shunt peaking coils L_1 and L_2 and the plate load resistor R_4. As indicated, the video signal is taken from the junction between L_1 and R_4 and applied to the sync separator. It is also coupled through blocking capacitor C_4 and series peaking coil L_3 to the cathode of the picture tube. As in Figure 9, the circuit of Figure 10 requires a negative picture phase signal in the video output circuit, since the cathode is employed as the input electrode of the picture tube.

Potentiometer R_6 is the brightness control. Its slider applies the desired bias through R_5 and L_3 to the V_2 cathode. Thus, the cathode is positive with respect to the grid which connects to ground. Adjusting R_6 changes the operating point of the picture tube and thus determines the brightness of the picture.

In the video amplifier cathode circuit, variable resistor R_2 permits changing the degenerative feedback in this stage in the same manner explained for the circuit of Figure 9. Therefore, R_2 serves to control picture contrast by varying the video amplification.

Each designer has his own particular preferences regarding the best means of accomplishing a given result. However, the basic requirements of each stage are the same for one television receiver as for the next. Therefore, the majority of video amplifier circuit designs consist of one or another of those arrangements which have proven satisfactory. The circuits of Figures 8, 9, and 10 are representative of commonly employed arrangements.

However, in addition to these, there are video circuits which differ considerably from the most used methods. As an electronic technician, you will have to employ your knowledge of circuit theory together with your understanding of the requirements of a stage to analyze the various "unusual" arrangements you encounter.

An example of such a circuit is given in Figure 11. Here, the two-stage video amplifier employs pentodes V_1 and V_2. However, the V_1 stage operates in a manner somewhat different from those described previously. The plate load consists of two resistors, R_2 and R_3, which form a voltage divider for the video signal voltage across them. The total a-c plate voltage is applied to the sync separator, and the voltage across R_3 to the agc circuit. This is the arrangement employed in the circuit of Figure 9.

However, in Figure 11, these are the only outputs taken from the plate circuit. Here, the screen grid operates as a second output electrode. Notice there is no screen bypass capacitor. Any varying screen current through shunt peaking coil L_3 and load resistor R_4 causes the screen voltage to vary in the same manner as the plate voltage. Thus, the video signal is coupled from the V_1 screen grid through capacitor C_2 to the control grid of V_2. Operating in the usual manner, the video output stage amplifies the signal and applies it through C_4 to the grid of the picture tube.

PHASE DISTORTION

In addition to providing uniform gain for all frequencies in its pass band, the video amplifier should cause equal phase shifts. Reviewing basic tube action, the a-c component of the plate current is in phase with the control grid voltage but 180° out of phase with the plate voltage. Therefore, in passing through an amplifier tube, the signal voltage has a theoretical phase shift of 180°. However, due to the capacitances associated with the circuits of a video amplifier, the current — voltage phase angles are not the same for all frequencies, therefore the angle of phase shift varies.

A table model television receiver.
Courtesy Andrea Radio Corp.

Due to this action, the amplifier delays some signal components, with respect to others so that in the output, the phase angles differ from those of the input. This time delay is known as PHASE DISTORTION. In television, phase distortion causes very noticeable and undesirable distortion of the reproduced image.

To illustrate this image distortion, the sine wave curves of Figure 12 represent video amplifier output signal voltages applied to the control grid circuit of the picture tube. As explained previously, variations of control grid voltage cause corresponding changes of brightness on the screen. For simplicity it is assumed that signals between 0 and +10 volts produce light grey areas, above +10 volts white areas, between 0 and −10 volts dark grey areas and below −10 volts black areas.

Thus, in Figure 12A, signal voltage e_{g_1} produces the areas shown along scanning line 1. In the same way, with no phase distortion, signal voltage e_{g_2}, with a frequency twice that of e_{g_1}, produces the areas shown along scanning line 2. However, circuit capacitance effects may cause the higher frequency signal e_{g_2} to be delayed more than e_{g_1}, in which case the respective areas or elements along line 2 occur a definite small interval of time later than when no phase distortion exists. When the video signals pass through several stages of amplification a total phase difference of as much as 45 degrees may be produced as shown in Figure 12B.

The effects in the image are shown by a comparison of the respective pairs of scanning lines. The elements of scanning line 2, Figure 12B, are shifted horizontally to the right with respect to their normal positions shown in

Figure 12A. If, as in practice, this effect is produced over the entire screen area, the picture is changed, or distorted.

For simplicity, only two scanning lines have been shown with a single sine wave signal applied to each. Actually, the television video signal consists of many components supplied to the picture tube control grid simultaneously during every scanning line. The intensity of each picture area is proportional to the resultant of all these signal components.

Similar to the action of Figure 12, if the higher frequency components are delayed a longer period of time than the medium frequency components, the signal voltage and resulting reproduced image are distorted. Phase distortion is also a result of excessive lead angles of the low frequency signal components. This produces uneven shading of the background and false contrast effects between light and dark areas of the image.

As with frequency distortion, phase distortion at the high frequencies is a result of the effects of the circuit shunt capacitances, C_0 and C_I, Figure 5A. At the low frequencies, it is a result of the effects of the coupling, cathode bypass, screen bypass, and power supply filter capacitors, C_c, C_k, C_s, and C_p, respectively.

Fortunately, the methods employed to obtain wide frequency response are effective in minimizing phase distortion also. As mentioned, these include the use of tubes having low interelectrode capacitances, low value plate load resistors, high value coupling and bypass capacitors and grid resistors, as well as the various compensating components and filters described. Although minor variations in peaking coils, etc., can be made to favor the phase response over the frequency response, or vice versa, a compromise of values gives good performance for both.

VIDEO AMPLIFIER TROUBLES

To provide a picture of good quality, the video amplifier must increase the strength of the video signal to the proper level with minimum frequency and phase distortion. The designer has selected component values and operating voltages to obtain this desirable operation. If circuit values change due to the development of a fault, or if replacement parts are employed with values different from the original values, the response of the video amplifier is altered. Any such change in response affects the picture quality in some way.

For example, loss of fine detail in the picture indicates that the high frequency response is poor. Analyzing this condition, it may be due to any of the factors which determine the video amplifier response at high frequencies. A shorted peaking coil would reduce the required peaking action to lower the high frequency gain. High-frequency amplification might be reduced if the wiring were disturbed to increase the stray shunt capacitance. If the plate load resistor were replaced by one of higher value, the stage gain would be higher over the middle range, but would drop off considerably at the high frequencies.

A smearing or streaking effect in the picture is caused by phase distortion. Another effect of this distortion is a gradual change in shading from the top to the bottom of the picture. Coupling and bypass capacitors which are too low in capacitance are a frequent cause of this trouble. Common offenders are the electrolytic capacitors used in the low frequency compensation circuits.

The edges of objects in the picture represent sudden changes in shading, either from light to dark or from dark to light. Such changes are produced by video signal pulses which contain many high frequency components. These high frequency components can cause momentary oscillations in the plate circuit of the video amplifier due to the peaking coil inductance and circuit capacitances. Called "overshoot", this action results when a peaking coil is not swamped sufficiently. The effect on the picture causes the edge of a light gray object to be outlined with a black line, and the edge of a dark gray object to be outlined with a white line. This picture distortion is known as "trailing reversal".

In all video amplifier circuits, the amplifier tubes and the plate loads serve to swamp or damp the peaking coils. However, additional damping is necessary in some cases, such as provided by resistors R_5 and R_8 in the circuit of Figure 9. Should one of these swamping resistors open, or increase in resistance, the coil would be insufficiently damped and produce trailing reversal. The same trouble might result if a swamping resistor is replaced with a resistor too large in value, or if a higher resistance solder joint is made when the swamping resistor or peaking coil is replaced.

Lack of clearness or crispness can be due to any circuit condition which reduces the amplification at high frequencies, as mentioned. A not-too-apparent cause of this picture defect is a shift in the operating point of the video amplifier tube. Such a shift may cause the parts of the picture signal corresponding to the whites to fall on the non-linear or curved part of the I_b-E_c characteristic. Then, the whites are amplified less than the remainder of the signal, resulting in reduced gradations of brightness for the light parts of the picture. This condition can be produced by any circuit defect that changes one or more of the video amplifier tube operating voltages.

In the video amplifier, and all the preceding stages, the picture information has the form of electric voltages and currents. However, neither voltages nor currents can be seen by a television viewer. A means is required by which the electric energy can be converted to light energy. This conversion is accomplished by the picture tube.

Actually, a large special type of electron tube, the picture tube, accepts the electric energy from the video amplifier and produces a pattern of light which corresponds to the scene at the transmitting studio. Emanating from the screen of the receiver, this pattern of light forms the picture seen by the viewer.

The construction and operation of this all-important device, the picture tube, is the subject of the next lesson.

* * *

IMPORTANT DEFINITIONS

BRIGHTNESS—The luminous intensity of a surface in a given direction per unit area of the surface as viewed from that direction.

BRIGHTNESS CONTROL—A potentiometer in the grid-cathode circuit of the picture tube. Provides manual adjustment of the operating point of the picture tube.

CONTRAST—The degree of difference between the lightest and darkest areas of the image on the cathode ray tube screen.

CONTRAST CONTROL—A variable resistor which varies the strength of the video signal applied to the picture tube.

D-C COMPONENT—A direct current component of the video signal. Carries information regarding the background brightness of the scene.

PEAKING COIL—An inductor used in video amplifiers to compensate for high frequency attenuation.

SOUND TRAP—An LC circuit, tuned to 4.5 mc, in the video section of the television receiver. Prevents the sound i-f being applied to the picture tube.

VIDEO AMPLIFIER—A wideband amplifier which increases the detected video signal to the level required to drive the television receiver picture tube.

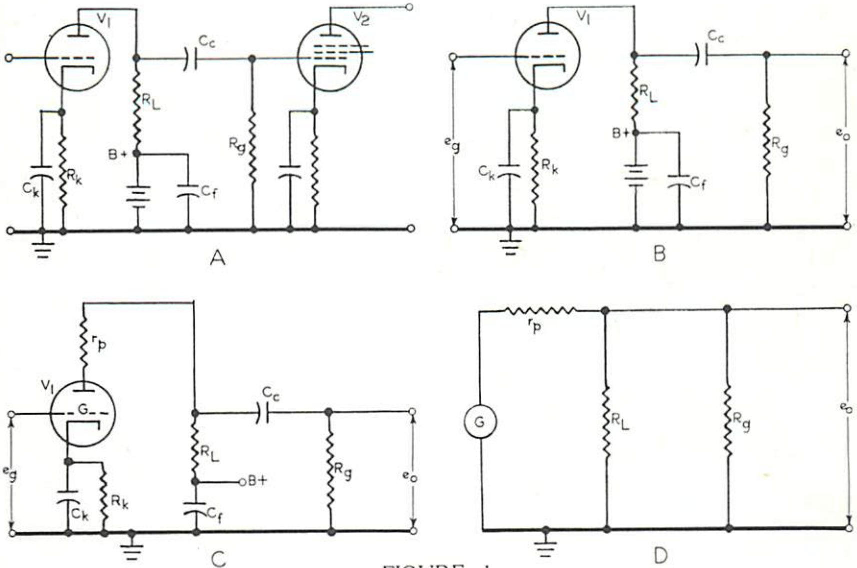


FIGURE 1

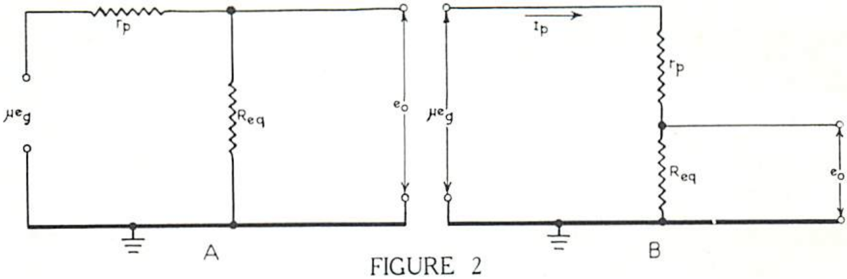


FIGURE 2

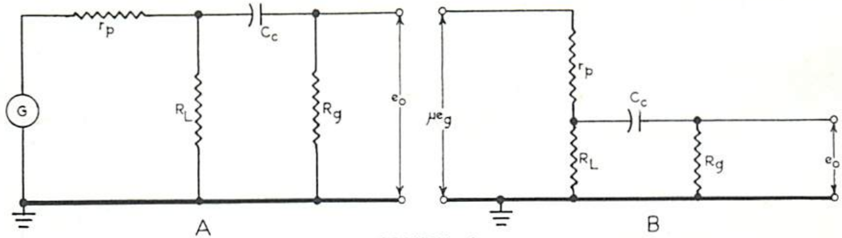


FIGURE 3

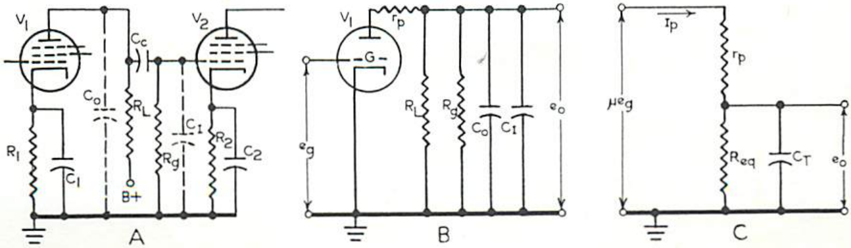


FIGURE 4

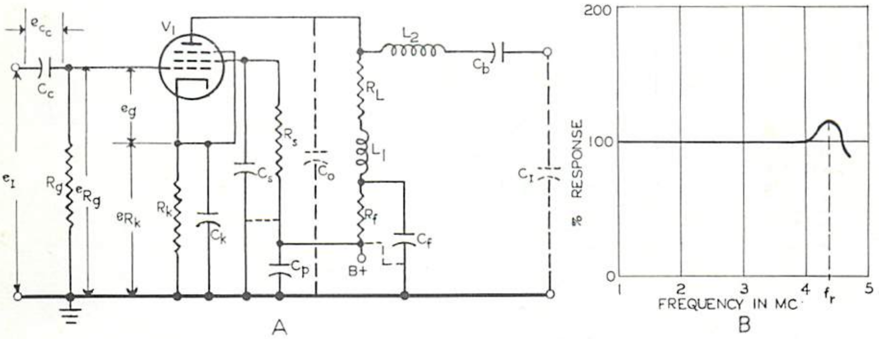


FIGURE 5

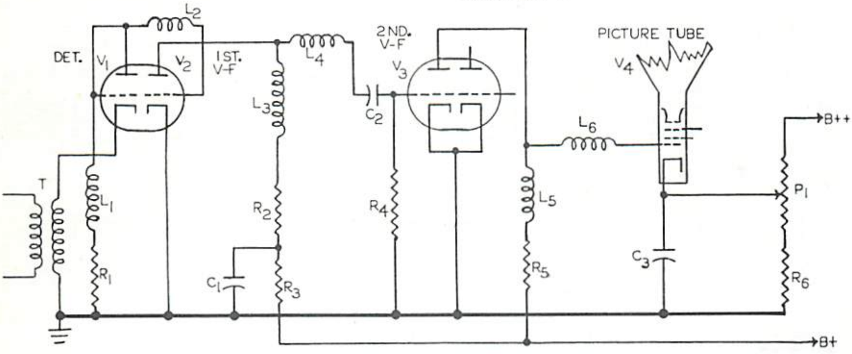


FIGURE 6

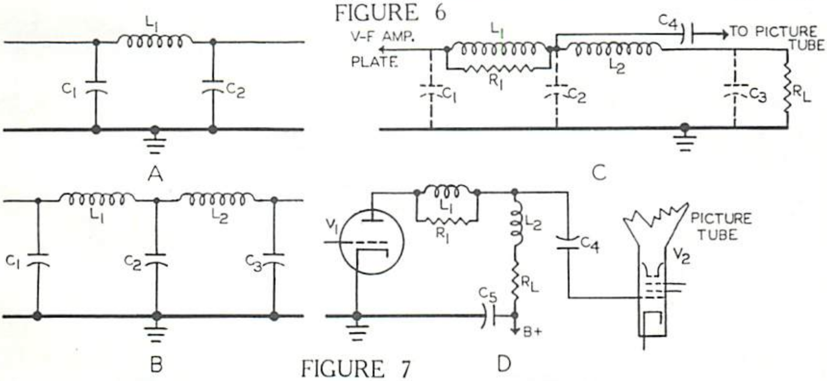


FIGURE 7

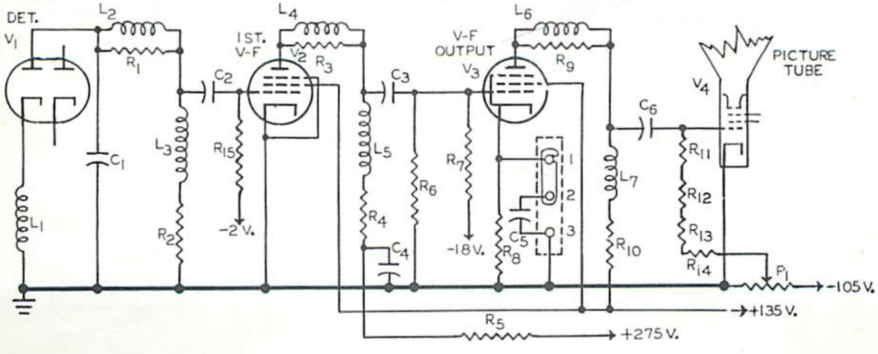


FIGURE 8

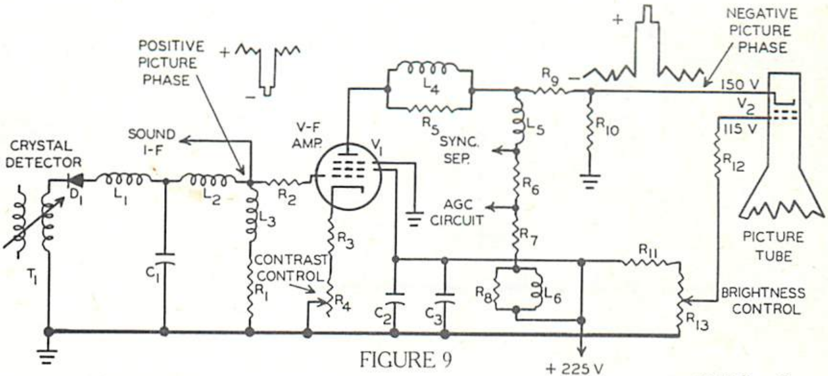


FIGURE 9

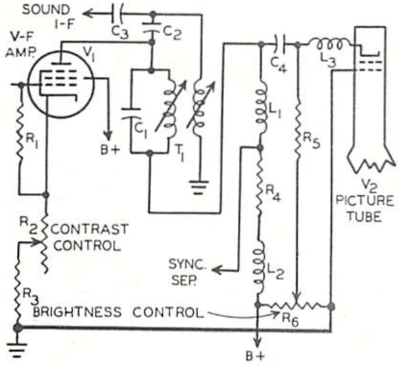
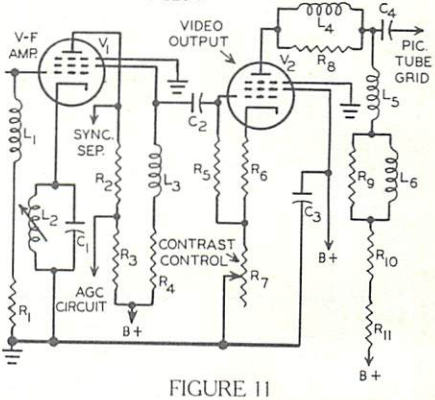


FIGURE 10



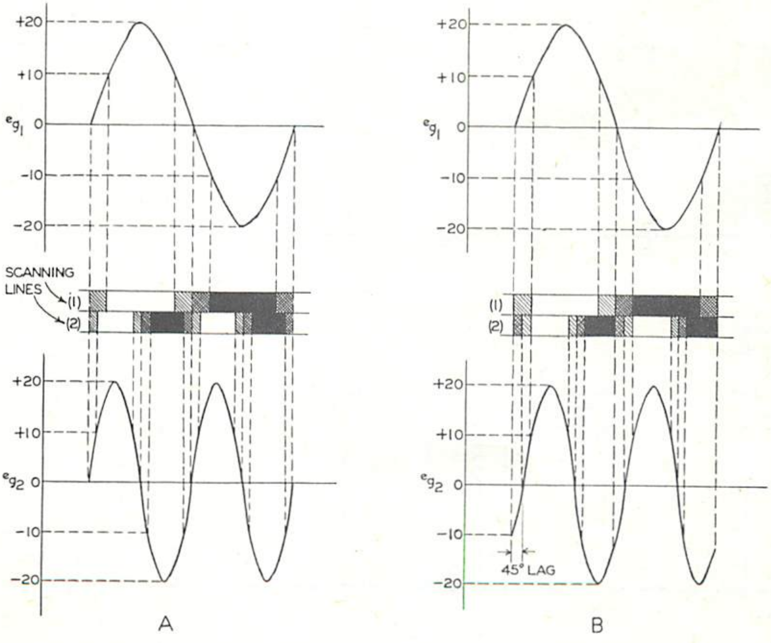


FIGURE 12

FROM OUR *Director's* NOTEBOOK

GOOD LOSERS

Most men can win gracefully, but to lose with a smile is not such an easy thing. Yet in this world no man can expect to be always a winner, and he had better learn to lose as cheerfully as he can.

It must always be remembered that the man who is a good loser is not necessarily indifferent to the result of his efforts. He will never lie calmly down after defeat. On the contrary, he will make every loss a stepping stone to victory. He will go over the lost game most carefully and see where he failed; and he will learn by his defeats. He will look far ahead and plan for future victories even while the defeat is fresh in his mind.

Yours for success,

W. C. DeVry
DIRECTOR

PRINTED IN U.S.A.